Water Quality Evaluation of Isabella Lake in Preparation for Dam Remediation

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I. ISABELLA LAKE BACKGROUND

Isabella Lake is a reservoir made up of two earthen dams on the Kern River about 40 miles northeast of Bakersfield, between the towns of Lake Isabella and Kernville in California (Figure 1). The dams were completed in 1953 to provide flood control, irrigation, and recreational benefits. The Main Dam is 185 feet high and 1,725 feet long and the Auxiliary Dam, 2,000 feet away, is 100 feet high and 3,257 feet long. Together, the dams provide 570,000 acres-feet of storage space at full capacity. The dams protect more than 300,000 people located in the Bakersfield area and about 350,000 acres of agricultural land and oil fields. The dams are operated and maintained by the US Army Corps of Engineers (USACE), while the park facilities are operated and maintained by the US Forest Service.

Isabella Lake falls within the Tulare Basin which is regulated by the Tulare Lake Basin Plan. TheBasin Plan has been approved by the Central Valley Regional Water Quality Control Board and establishes water quality objectives to ensure reasonable protection of beneficial uses and an implementation program to achieve these objectives. Water quality objectives are stated for parameters such as: dissolved oxygen, electrical conductivity, turbidity, pH, and a variety of metals. The Basin Plan also documents the following surface water beneficial uses for Isabella Lake: hydropower generation (POW), water contact recreation (REC-1), non-contact water recreation (REC-2), warm freshwater habitat (WARM), cold freshwater habitat (COLD), wildlife habitat (WILD), and freshwater replenishment (FRSH). Isabella Lake is responsible for both COLD and WARM fish, however due to the warmth of the water, coldwater fish species find it difficult to breed and survive year round. Warm water fish species found in the lake include Hardheads, Sacramento Pikeminnow, Sacramento Sucker, Riffle Sculpins, Smallmouth Bass, Largemouth Bass, Channel Catfish, Carp, Bluegill, and Crappie.

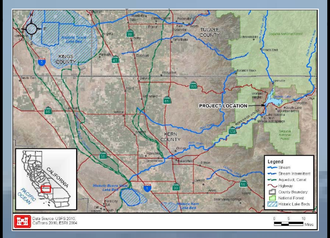


FIGURE 1: Project Location

II. ISABELLA DAM REMEDIATION

In 2005, the USACE determined through a risk assessment process based primarily on life safety that the both Isabella Dams posed unacceptable risk. Therefore, the Isabella Dam facilities require structural improvements to safely meet authorized project purposes and to reduce risk to the public and property from dam safety issues posed by floods, earthquakes, and seepage. Remediation alternatives are being considered as part of the Isabella Lake Dam Safety Modification (DSM) Project. Construction is anticipated to begin in 2015.

The USACE implemented a pool restriction based on the seepage concerns to reduce risk in the interim until the USACE completes design of the permanent solution alternative. The current pool restriction is 20 feet below full pool level (elevation of 2585.5 feet), or 63% of full capacity, during the flood control off-season, from March through September.

Water quality parameters are being monitored on a monthly basis (see "Current Monitoring Activities" for more information). By collecting data, a water quality profile can be developed and the USACE can check compliance with federal and state regulations for drinking water and aquatic life limits as well as more local objectives set by the Tulare Basin Plan. In the future, with the anticipated remediation activities, other water quality regulations will need to be adhered to such as the California Construction General Permit (CGP) for storm water.

FIGURE 2: Multi-sensor sonde (top) and monitoring buoy at the Main Dam (bottom)

		Temperature (°C)		Dissolved Oxygen (mg/l)		pH (units)		Conductivity (µS/cm)		Turbidity (NTU)	
		Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
Spring (March, April, May)	Main Dam	10.14 - 15.52	8.88 - 13.39	8.74 - 11.16	4.12 - 10.45	6.87 - 8.2	6.5 - 8.05	88 - 138	73 - 137	0 - 62.5	1.9 - 113.2
	Auxiliary Dam	9.75 - 15.45	9.52 - 15.34	8.31 - 11.31	6.84 - 10.57	6.3 - 8.13	6.89 - 8.28	88 - 139	80 - 166	0 - 121.2	5.5 - 118.2
Summer (June, July, August)	Main Dam	16.26 - 25.32	12.3 - 21.54	8.15 - 10.12	0.23 - 8.89	5.89 - 8.81	6.24 - 7.6	70 - 104	58 - 103	0 - 29.9	1.3 - 58.5
	Auxiliary Dam	15.61 - 23.74	14.79 - 22.55	7.07 - 10.32	4.5 - 9.38	6.49 - 8.54	6.59 - 8.27	69 - 103	61 - 105	0 - 19.6	0 - 42.7
Fall (September, October, November)	Main Dam	12.25 - 23.51	11.45 - 21.85	5.24 - 11.86	0.02 - 9.74	5.78 - 8.01	6.03 - 7.62	79 - 127	95 - 129	0 - 7.5	0 - 30.7
	Auxiliary Dam	11.79 - 22.95	11.63 - 21.9	6.46 - 11.74	1.11 - 11.67	5.98 - 7.89	6.05 - 7.87	79 - 128	79 - 128	0 - 8	0 - 43.8
Winter (December, January, February)	Main Dam	6.49 - 9.96	6.09 - 9.64	10.28 - 16.44	9.01 - 14.34	5.06 - 8.25	6.26 - 8.07	104 - 159	104 - 159	0 - 6.8	3 - 39.4
	Auxiliary Dam	6.22 - 9.5	6.08 - 9.32	9.5 - 16.9	7.6 - 16.27	5.81 - 8.17	6.73 - 8.25	103 - 158	103 - 157	0 - 9.6	4.9 - 136.3
Tulare Basin Plan Water Quality Goals	Isabella Lake	Natural temperature of waters shall not be altered.		Minimum for Isabella Lake: 8 Minimum for COLD: 7 Minimum for WARM: 5		6.5 - 8.3		Maximum of 300		Natural Turbidity	Increase not to exceed
										0 -5	1 NTU
										5 - 50	20%
										50 - 100	10 NTU
										> 100	10%

TABLE 1: Seasonal Ranges for Collected Water Quality Parameters (April 2009 – March 2012) and Tulare Basin Plan Water Quality Goals

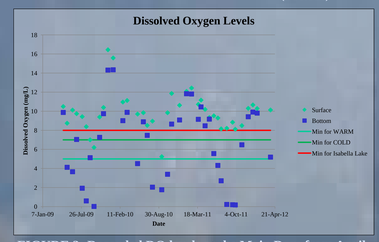


FIGURE 3: Recorded DO levels at the Main Dam from April 2009 to March 2012 and associated Tulare Basin Plan goals.

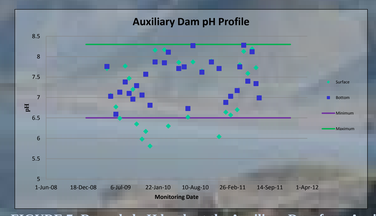


FIGURE 7: Recorded pH levels at the Auxiliary Dam from April 2009 to December 2011 and associated Tulare Basin Plan goals.

III. CURRENT MONITORING ACTIVITIES AND WATER QUALITY CONDITIONS

A field team from the USACE Sacramento District visits the reservoir monthly to monitor a wide range of parameters using a Hydrolab ™ Multiprobe sonde, as shown in Figure 2. Water quality data is obtained from the Kern River's north and south fork inlets and both the Main and Auxiliary Dam outlets. Water quality profiles are also taken upstream of both dams at the presumed deepest locations; data is collected at 1-meter intervals to examine the reservoir's strata. Figure 11 shows the monitoring locations where data is collected during each visit. The collected data includes water depth, temperature, pH, conductivity (salinity), dissolved oxygen (DO), and turbidity. Data is also collected on an hourly basis in the top 1 meter of the reservoir by a sonde housed in a buoy near the Main Dam (Figure 2). The buoy was installed in April 2011. This time resolution will be more relevant to expected conditions that need to be analyzed during any remediation activities.

Table 1 shows the seasonal ranges of select parameters collected between April 2009 and March 2012 with the associated water quality goals determined by the Tulare Basin Plan. Isabella Lake's pH and DO are prone to exceed the water quality standards set by the Tulare Lake Basin Plan, especially in the summer and fall. The Central Valley Regional Water Quality Control Board is working towards listing Isabella Lake on the Clean Water Act 303(d) list for pH and DO due to their exceedance of the Basin Plan's water quality objectives and impacting cold freshwater habitats (CSWRCB, 2010). Total Maximum Daily Loads (TMDLs) are anticipated to be completed in 2021. Figures 3 and 4 show a more detailed graph of the DO and pH ranges collected throughout the year and the corresponding Tulare Lake Basin Plan water quality objectives for Isabella Lake, WARM, and COLD.

The spring temperature profiles for Isabella Lake at the Main Dam and Auxiliary Dam are indicative of a well-mixed lake (Figure 8). This is likely due to the high winds experienced daily at the lake. For more information, see section "Mixed Water Column." Isabella Lake is a warm climate lake with summer water temperatures greater than 20°C. Due to the warmth of the water, coldwater fish species would find it difficult to breed and survive year round.

The USACE's historical water quality monitoring has also discovered periods of high arsenic levels at the bottom of the lake which exceed drinking water standards. The comparison criteria used is based on drinking water limits, but according to the Basin Plan, Isabella Lake is not used as a municipal water source. However, downstream from the dam, the Kern River is used as a source of drinking water.

FIGURE 4: Typical Thermal Stratification

FIGURE 5: Pictures of wind waves on Isabella Lake

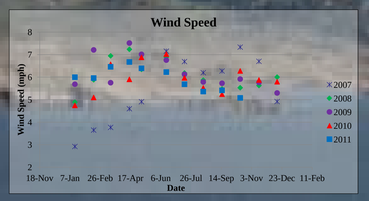
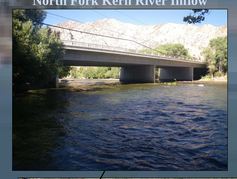
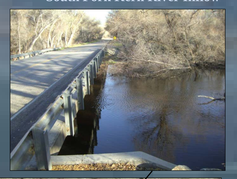


FIGURE 6: Wind Speed Values Recorded near the Main Dam from 2007 to 2011.

North Fork Kern River Inflow



South Fork Kern River Inflow



Main Dam Outflow

Auxiliary Dam Outflow

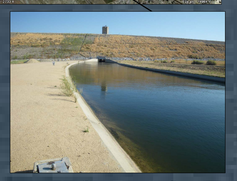


FIGURE 11: Current Monitoring Locations

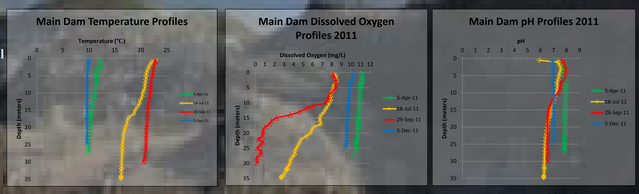


FIGURE 8: Three graphs representing the temperature, dissolved oxygen, and pH profiles from each season in 2011.

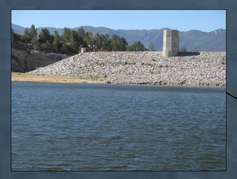
IV. MIXED WATER COLUMN

Lakes similar in altitude and latitude as Isabella Lake are classified as warm monomictic thermal lakes, such as Lake Kaweah and Lake Success (Figure 9). These lakes typically circulate freely once a year in the winter at or above 4°C, and are stably stratified for the remainder of the year. Stable stratification is a result of the water column thermally dividing into three regions which are typically resistant to mixing with each other, as seen in Figure 4. The deepest stratum, the hypolimnion, is made up of a cold, dense, relatively undisturbed layer of water. The upper stratum, the epilimnion, is made up of uniformly warm, circulating, and fairly turbulent waters. The middle stratum, the metalimnion, is characterized by a strong temperature gradient as the upper and lower stratums intersect.

However, Isabella Lake does not follow the warm monomictic characteristics as is expected from its location. As seen in Figure 8, the temperature profile for Isabella Lake represents a polymictic thermal lake type which is characterized by frequent or continuous periods of mixing during the year. Data collected from the monthly water quality trips have shown evidence of the lake being completely mixed the majority of the year. There are brief periods of stratification during the summer and fall, but the majority of the lake is still well-mixed. Figure 10 displays the temperature profile of the three lakes (Isabella, Success, and Kaweah) during monitoring events in spring of 2009. This figure shows the mixing characteristics of each of the lakes, Isabella Lake's curve represents a completely mixed water column while the curves from Lake Success and Lake Kaweah show evidence of the three strata.

Isabella Lake is regularly subjected to high winds which are the most likely cause of the unique mixed characteristics of the lake. As seen in Figure 5, wind energy mechanically distributes most of the heat in the epilimnion with the use of waves to mix the water. As wind blows over the surface for a substantial period of time, wind drift causes water to pile up, with a rise in surface level at the lee end of the lake. During this process the thermocline level lowers which increases the upper mixed layer of the lake. In the past five years, the predominant winds have been south-southwest with an average wind speed of almost 6 mph (Figure 6). When the wind direction is south southwest, the wind blows water in the lake towards the Auxiliary Dam. As the water reaches the dam, waves crash against the rip rap and create aeration of the water. This effect helps produce higher levels of dissolved oxygen in the lake, especially at the Auxiliary Dam.

FIGURE 9: Locations of Lakes Kaweah, Success and Isabella



Main Dam Profile Location

Auxiliary Dam Profile Location

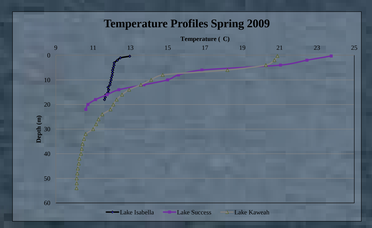
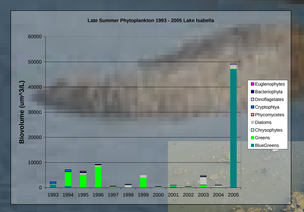


FIGURE 10: Temperature Profiles showing Isabella Lake's mixing characteristics compared to the stratification of Lakes Success and Kaweah



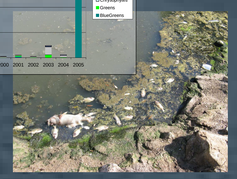


FIGURE 12: High levels of blue green algae such as those seen in Summer 2005 (top) can lead to fish kills (bottom)

V. REMEDIATION ACTIVITY CONCERNS

If the selected remediation alternative includes construction, Isabella Lake's pool level will be drastically lowered to fully expose the dams for repair. Table 1 and Figures 3 and 7 show that the Tulare Lake Basin Plan water quality objectives are not always met under natural conditions; construction activities will likely cause additional problems meeting regulations. If construction activities cause prolonged degraded water quality, the lake's numerous beneficial uses will be in danger. For example, if the dissolved oxygen levels drop, there will not be enough available oxygen in the water column for some fish species to survive. Additionally, due to the unique mixed water column characteristics under natural conditions, a lowered pool level will lengthen the settling time for sediments throughout the lake. An increased sediment load will likely cause the water quality to further degrade. The main areas of concern for water quality based on baseline monitoring include: compliance with state and federal regulations now and in the future, the possible implications of construction activities around a lake that remains fully-mixed throughout the seasons, arsenic levels in the lake that are near and sometimes above the drinking water limit, and hazardous algal blooms which are suspected to have caused fish and bird kills in the past (Figure 12).

VI. FUTURE MONITORING ACTIVITIES

An extensive monitoring program is being implemented at Isabella Lake. The USACE will be installing additional buoys upstream of the Auxiliary Dam and in two other locations to better characterize the reservoir's background water quality. Each buoy will house two multi-sensor sondes to collect readings at regular intervals (about once every hour). The sondes will be placed at approximately 1-meter from the surface and one approximately 5-meters below the surface which will be suspended by a cable. Each multi-sensor sonde will house the following sensors: temperature, conductivity, optical dissolved oxygen (DO), pH, depth, integrated chlorophyll, oxidation reduction potential (ORP), and a self cleaning turbidity sensor. The new buoys and multiprobes are anticipated to be purchased and installed this summer of 2012. All buoys will be equipped with a telemetry system that will allow for data to be viewed almost instantaneously from any computer. The buoys will be kept in place during construction so that water quality can be closely monitored.

Water quality data at Isabella Lake will continue to be monitored and collected to determine baseline parameters. The baseline parameters will be used to compare the water quality of the lake during remediation activities. After the seepage, seismic and hydrology issues have been repaired in the dams, it is the USACE's goal to ensure the lake's water quality is restored to its natural state, as determined by these baseline investigations.

ACKNOWLEDGEMENTS: We would like to thank all of the USACE employees that worked and provide support to the Isabella Lake water quality effort. We would also like give special thanks to Veronica Petrovsky, Adam Riley, Mitch Stewart, John Esparza, Brad Call, Suzette Ramirez, Roxanne Dickinson, David Ho, Pete Arpin, Jack Shamblin, Don Willis, Josh Smalling, Matthew Johnson.

REFERENCES: Tulare Basin Plan, Isabella PMP, Isabella Lake Dam Safety Modification (DSM) Project EIS (2012), Limnology by Robert Wetzel, the CSWRCB's Clean Water Act Section303(d) List/305(b) Report, and the DSM website: http://www.spk.usace.army.mil/projects/civil/Lake_Isabella_Dam/Index.html